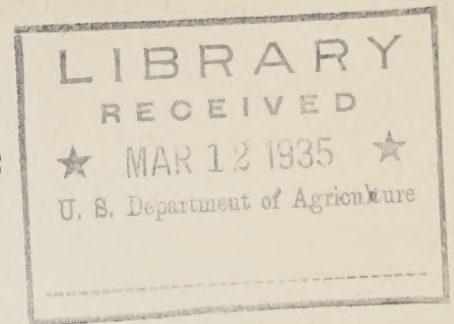


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UNITED STATES DEPARTMENT OF AGRICULTURE
Bureau of Agricultural Engineering
S. H. McCrory, Chief



MEMORANDUM FOR E.C.W. CAMPS IN NEBRASKA
RELATIVE TO TERRACES AND OTHER EROSION CONTROL STRUCTURES

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March, 1935

COOPERATIVE WORK IN EROSION CONTROL

This memorandum has been prepared for the guidance of the erosion control camps working on agricultural lands in Nebraska.

Where a farmer agrees to construct and maintain terraces in a field, to fill across all minor gullies, and to discharge terraces into a common outlet, the ECW camp is authorized to plan the erosion control system, stake out the terraces, cooperate in controlling terrace outlet ditches with erosion control structures, and plant large gullies. On this work the farmer does the earth moving jobs including terracing, gully fills and outlet ditch construction which require tractors or horses and graders, and the camps do the parts of the job requiring large amounts of hand labor. This cooperative plan has proved to be one of the most practical and economical work programs for ECW camps working on agricultural lands. The primary part of a permanent erosion control system is provided on fields treated in this manner. Protection by this means is often less costly than checking erosion in each gully with a series of temporary dams, as is necessary when the terrace system is not constructed.

It is desirable to have landowners take some part in the erosion control work because when they assist with the construction they immediately become interested in proper maintenance. Checking erosion in the gullies only, on cultivated areas, is at best only a partial and temporary check of improper drainage conditions for the slopes and vegetative cover of the field.

Although terracing is the foundation of an erosion control and moisture conservation project, the problem is not completely solved by terracing. One of the principal farm practices which should be followed in connection with terracing is contour farming with the terraces serving as guide lines for contour cultivation. This practice is strongly advocated. A terraced field with lister furrows on the contour has been known to hold all of a 2-inch rain. When a field is plowed it should always be back-furrowed toward the terrace. This will make the terrace higher and wider. Each terrace will become an integral part of the field, be much easier to farm over, and maintenance will be reduced to a minimum. Considerable attention should be given to agronomic practices, that is, the planting of soil-building crops and permanent pasture on thin, steep, and badly worn-out land, proper crop rotation, strip farming, and other beneficial practices. Cropping, however, is done by the farmers and does not provide a work program for the camps.

Correction of drainage by terraces is a construction project that requires machines and power available to landowners, and protection to terrace outlets requires a large amount of hand labor. Where the camps can plan and lay out terrace systems and supply the hand labor that the farmer does not have available, they are doing work that most landowners would neglect indefinitely. Through this program the camps not only reduce the cost per acre as compared to working gullies separately, but they also arouse the farmer's interest by gaining his cooperation, and the completed project serves to check erosion on the entire field.

Many small, washed-out areas should be planted to trees or permanent cover crops rather than terraced. Others should be terraced and then planted. Gullies too large to terrace across should be protected by terracing all water away from them. Little or no dam building will then be necessary in the gully channel for planting purposes. The large gully so protected can be planted to trees to produce posts, logs, and other valuable timber products for the farm.

The planting of trees is of vital importance in a program of this kind. They should be planted (1) as windbreaks to prevent wind erosion; (2) in reclaiming gullies; (3) below the discharge of a terrace outlet to prevent erosion and maintain the grade.

DESIGNING AND LAYING OUT THE TERRACES

As the first step in the design of a terrace system, a complete study should be made of the area. A rough sketch map may be made, using a compass and pacing the distances or a small military plane table may be used. A fairly accurate measurement of slopes should be shown and possible locations for the outlet ditch. Also the location and approximate size of gullies should be shown, ridges separating slopes, location of farm buildings, fences, etc.

With the aid of the sketch map, together with a physical inspection, the terrace outlet may be located. The outlet should be so located that terraces entering it from each side will be of approximately the same lengths. This will be partially true of large areas where terraces necessarily will be long. Locating the outlet in this manner will increase the value of any check dams constructed and will permit the construction of long terraces without overburdening them. If possible, advantage should be taken of any natural draw or depression for the outlet ditch location. In such places, the grade is usually less than in other parts of the field. This does not mean using a gully as a terrace outlet.

After the location of the outlet has been established it should be staked out. The ditch should be straight. In some cases it might appear advantageous to use a crooked gully which has already been formed as a terrace outlet. This is not good practice as a crooked ditch is difficult to control and might cut around a permanent structure, but if the outlet is made straight it will remain so and structures will not be jeopardized.

Changes in alignment should be made at a permanent structure. The crest of the weir notch of a structure at a turn should be at right angles to the center line of the ditch leading to the next structure below. In some cases it may be possible to utilize part of an old gully by straightening it but this will usually make it necessary to build structures higher than required and it is usually cheaper to open up a new outlet and build fills across gullies on terrace lines. (See fig. 1).

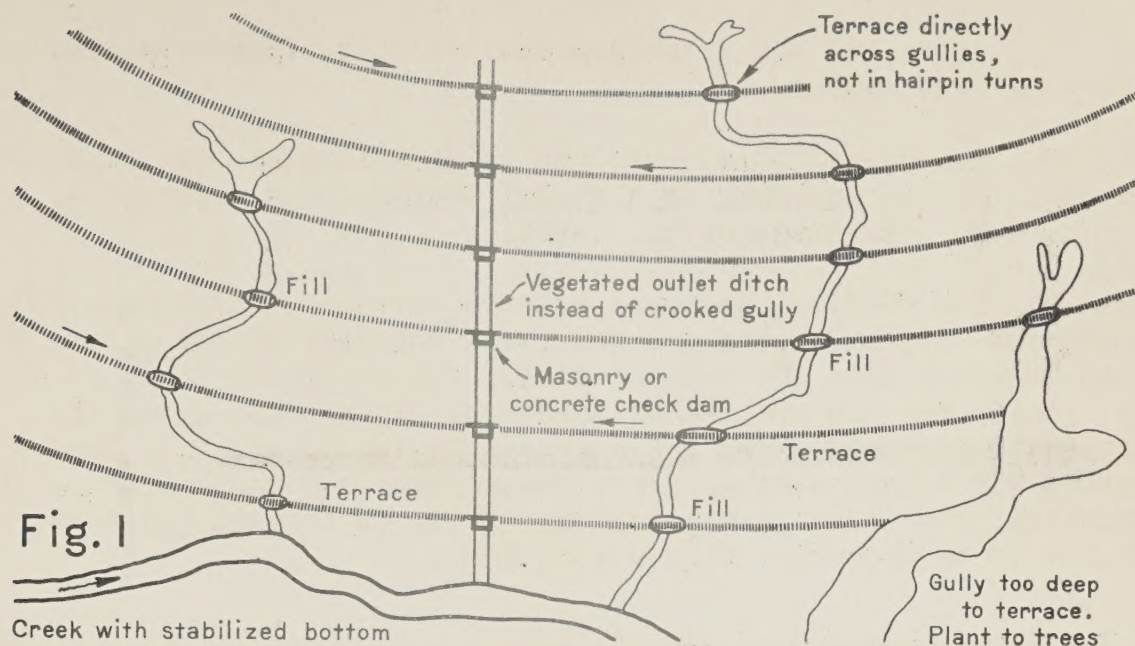


Fig. 1

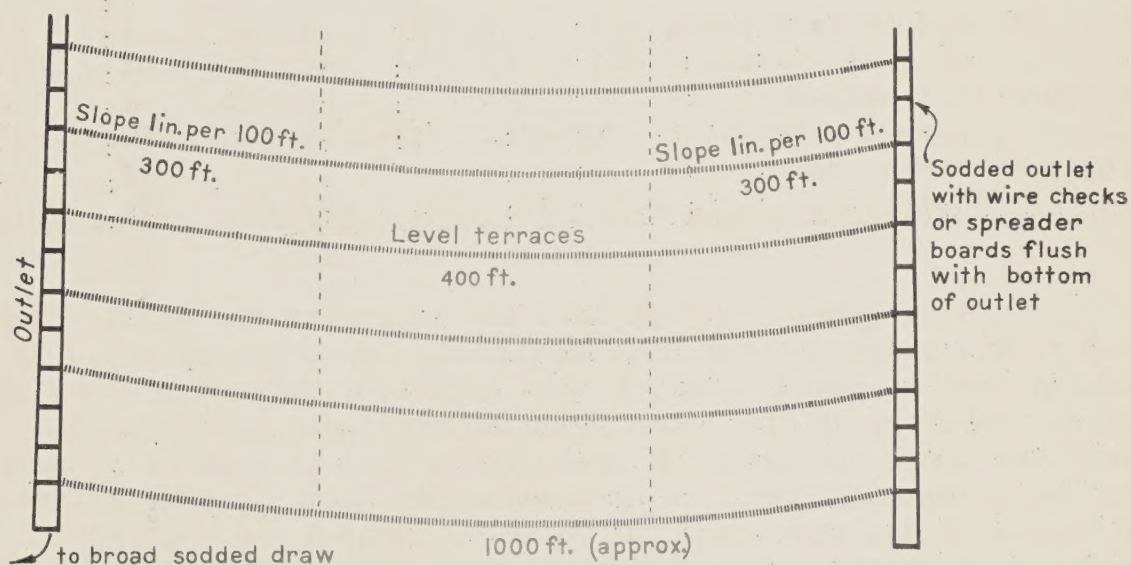


Fig. 4

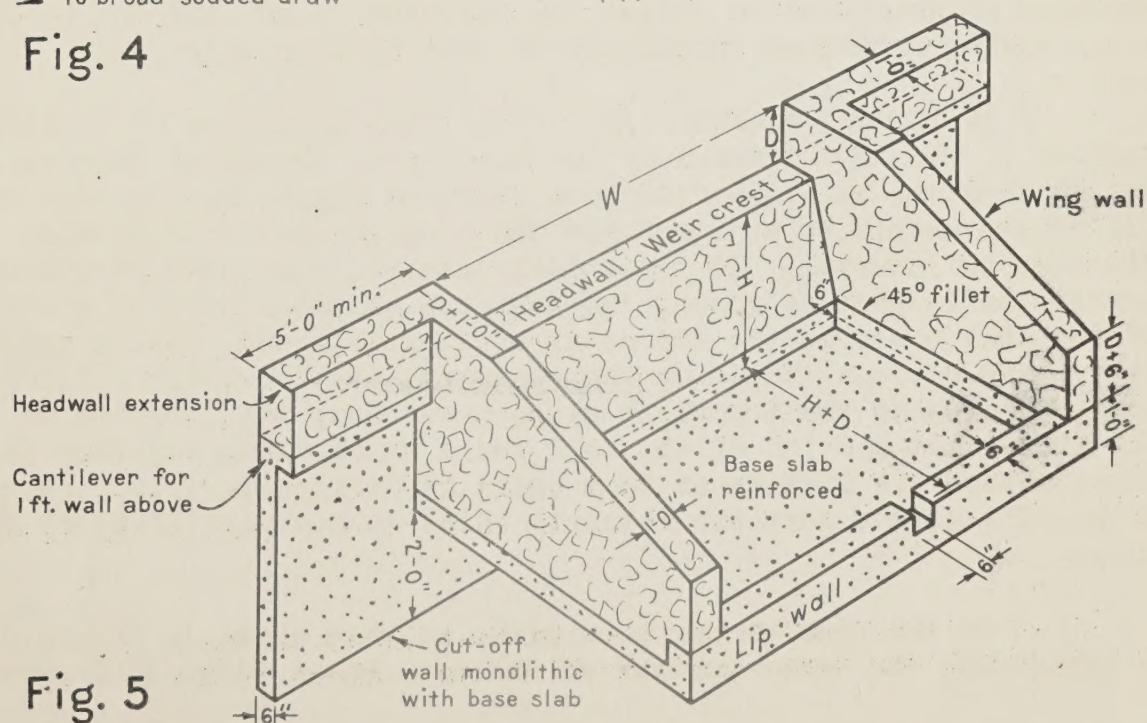


Fig. 5

There are two principal factors to be considered in designing a terrace system.

1. The slope of the land which determines the terrace interval or vertical drop between terraces.
2. The grade of the terrace.

The vertical interval between terraces and consequently the distances between terraces should be a function of the slope, taking into consideration the type of soil. The following table is furnished as a guide for the spacing of terraces. This table gives the schedule recommended for the northern States by the U.S. Bureau of Agricultural Engineering. Most States have recommendations which vary slightly from those of the Bureau. If it is thought advisable to follow State procedure this may be done.

	:	:	:	:	:	:	:	:	:
Slope of land in feet per	:	:	:	:	:	:	:	:	:
100 feet	1:	2:	3:	4:	6:	8:	10:	12:	:
Vertical fall between	:	:	:	:	:	:	:	:	:
terraces, feet....	2:2-3/4:	3:	3-1/2:	4:	4-3/4:	5-1/2:	6-1/4:	:	:
Distance between terraces,	:	:	:	:	:	:	:	:	:
feet.....	200:	137:	100:	88:	67:	59:	55:	52:	:

It is generally felt that the terracing and cultivation of land with a slope greater than 12 percent is not practical. It is usually best to devote land of this type to permanent pasture or trees. However, in the loess hills of northeastern Nebraska, excellent crops are grown on land with slopes as high as 20 percent. For terracing such land, it is recommended that a vertical interval of "one-half the slope per 100 feet" be adopted and that strip cropping be practiced to assist the terraces in holding the soil. This will require a minimum spacing of 50 feet between terraces.

It is very probable that there will be slopes of varying degrees in the area covered by one terrace or system of terraces. The problem may be similar to that shown in Figure 2. In this case all slopes should be measured and the average used to determine the terrace interval. If a vertical interval were used corresponding to the 12 percent grade, the terraces on the 6 percent portion of the hill would be too far apart horizontally and erosion would take place between them. On the contrary, if the vertical interval corresponding to the 6 percent slope were used, the terraces on the 12 percent portion of the hill would be so close together that construction and farming of them would be difficult. The average slope will give a vertical interval which is most satisfactory throughout.

Or the problem may be similar to that shown in figure 3. As indicated, the lower portion of the hill has a slope of 5 percent.

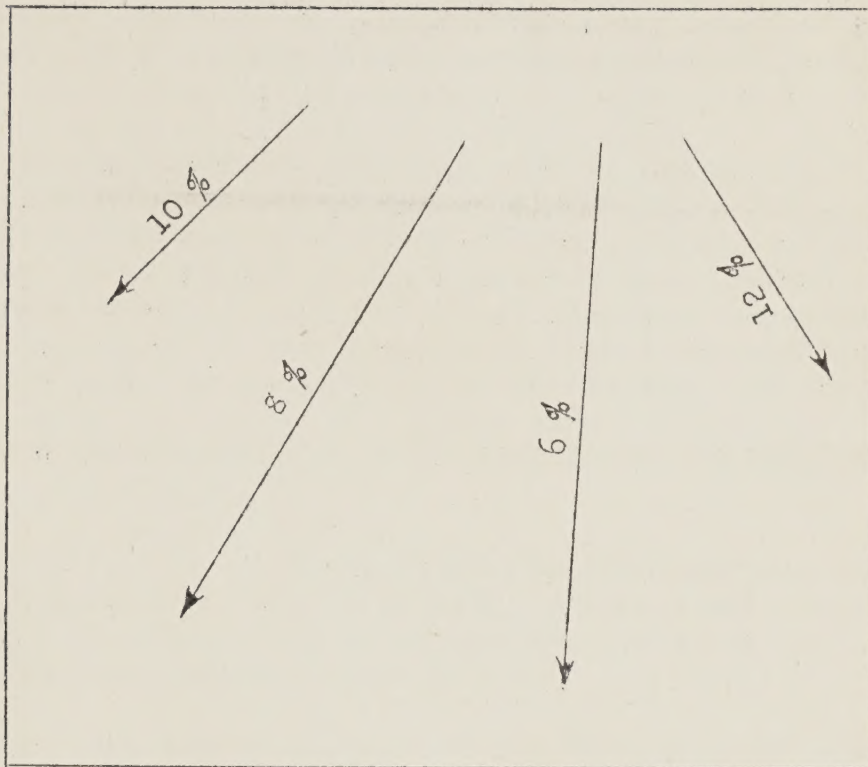


Figure 2

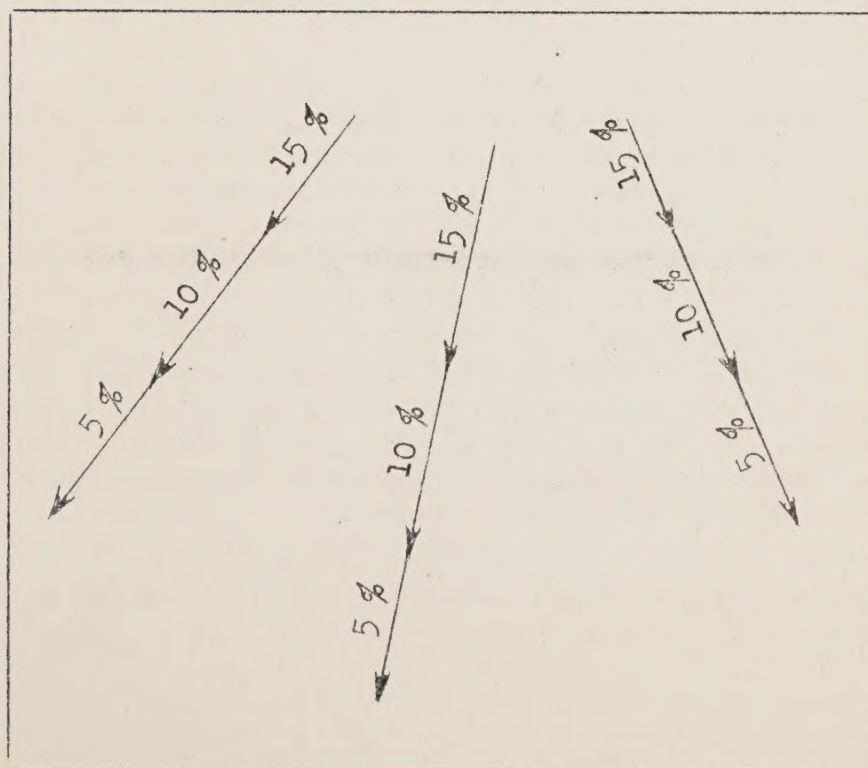


Figure 3

Further up the hill this increases to 10 percent and later to even 15 or 20 percent. In this case the average should not be taken. Each slope should be measured and a vertical interval used which is best suited to that slope. Determining the vertical interval to be used in spacing terraces requires sound judgment on the part of the engineer.

In laying out terrace systems, the watershed or terracable area and not land lines should be the controlling factor. This is particularly true where permanent outlet structures are to be built. In order to justify such structures, long terraces must enter them from each side. In general, 1,800 feet will be considered the maximum length of terrace entering a structure from either side. However, a longer terrace will operate satisfactorily if properly built.

For the maximum length terrace the following grade is suggested:

At the upper end	450 feet - level
next	450 feet - 1 inch grade per 100 feet
next	450 feet - 2 inch grade per 100 feet
last	450 feet - 3 inch grade per 100 feet

The same schedule may be used in laying out shorter terraces. In western Nebraska, where the rainfall is less than in other parts of the State, the level section of the terrace should be increased to 600 feet. This might also apply to the section ^{with} 1 inch per 100 feet grade.

The larger the area per structure the less the cost per acre for check dams. Where permanent check dams are used to control terrace outlets, an effort should be made to drain the largest area practicable into each controlled channel. The most economical project would be one that had terraces of maximum permissible lengths discharging into both sides of the outlet channel.

In small terrace systems, where the outlet is controlled with vegetation, it is not necessary to have terraces discharging into both sides of the outlet ditch. This type of control must be limited to small areas and the discharge from terraces on one side of the channel may load the ditch to the full capacity vegetative control will permit. It will often be found practical to divide the flow about the center of an area and use a vegetated channel at each side of the field, thus avoiding necessity for masonry or concrete structures, as would be needed if the run-off were concentrated in one outlet. Figure 4 shows how terrace outlets for a 30 or 40 acre field may be protected with vegetation. The possibility of discharging terraces onto a firm sod or brush cover should not be overlooked.

CONSTRUCTION OF TERRACES

The construction of terraces is similar to grading a road and the completed terrace should resemble a roadway with a high, narrow crown and a broad, shallow channel on the upper side. Terraces may be built with any type of equipment that will move earth. This may range from a homemade V drag to a 12-foot grader drawn by a Caterpillar tractor. The heavier equipment will build better terraces more rapidly and on a cost per mile or cost per acre basis is usually cheaper. There are several types of horse-drawn terracing machines on the market. These can be purchased in two sizes, 6 foot and 8 foot blades. Usually one horse per foot of blade is necessary on these machines to properly build terraces without overworking the stock. Terraces can be built with a 6-foot blade terracing machine and a small wheel tractor. The heavier equipment may often be secured from counties and townships at small cost. Every effort should be made to assist farmers in securing equipment for terracing.

Terraces may be built from both sides or from the upper side only. There are advantages in building terraces only from the upper side on steep slopes and from both sides on moderate slopes. The following practice is recommended:

- On slopes up to 6 percent - build from both sides.
- On slopes 6 percent to 12 percent - build mostly from upper side.
- On slopes greater than 12 percent - build all from upper side.

The person building the terraces may try both methods and use the one which seems best under his particular working conditions and equipment. In every case one round of the terracer should be made to backslope the outer edge of excavations. The completed terrace should be 24 to 32 feet wide and 18 to 24 inches high. The broader the terraces the easier they are to farm over; the higher they are the safer they will be against overtopping. The upper end of each terrace should be turned up hill to prevent water flowing out at this end, causing excessive erosion and reversing the grade of the terrace.

In every case the top terrace should be built first and should be adequate before the next one below is started. It is much better to build one full size terrace than half a dozen inadequate terraces which will probably break and do more damage than if the land had not been terraced. The top terrace should be started at a vertical distance from the top of the hill equal to the vertical interval between terraces as designated by the slope.

Terraces constructed on land which is to be planted in permanent pasture need not be as large as those built on cultivated fields.

In some cases a steep hill rises rapidly above a more gently sloping field. It may not be considered feasible to terrace this hill

but the field below it should be terraced. In this case it is necessary to build a diversion ditch at the upper side of the field. This ditch should be designed by application of hydraulic formulas, estimating run-off from "Brief Instructions on Methods of Gully Control," by C.E. Ramser. Ditches handling run-off from small areas can be designed from data included in W.D. Ellison's "Memorandum to ECW Technicians." The discharge from this ditch may be brought to the outlet serving the terrace system and discharged through it.

When a gully is encountered in a field to be terraced, earth fills should be built across the gully on the terrace line and water carried to the prepared outlet. The same care should be taken in constructing these fills as in constructing dams of any other type. All earth used in the construction of fills should be taken from gully banks upstream from the dam. In this way the gully will be filled by the regular farming operations.

PROTECTION OF OUTLETS

In the past it has been the policy, in many cases, to discharge terraces into roadside ditches or into gullies already formed. In almost every case this necessitates an overfall at the end of every terrace which, unless protected, will eventually cut back into the field and develop a gully along the terrace channel. This action also lowers the elevation at the end of the terrace, thus increasing the grade and starting scouring at a considerable distance from the outlet.

The concentration of water caused by discharging several terraces into a roadside ditch will result in serious erosion along the road and do great damage to the road as well as the field unless the ditch is protected against erosion. The best place to handle the discharge from terraces is on the land which the terraces serve. For this reason the outlet should be an integral part of the terracing system.

A terracing system is not complete until an outlet is provided and protected against erosion. The protection should extend down to base grade or to a nonerosive substance. By base grade is meant a creek bed in which the grade has been stabilized, or a broad, well-vegetated draw which will cause the water to be spread over a large area and thus minimize the possibility of erosion. By a non-erosive substance is meant a ledge or outcrop of durable rock which will serve as an overfall and not erode. It is often possible to use a concrete road culvert as the location for finally discharging the water from a terrace outlet. In many cases a concrete or masonry riser may be built on a road culvert, thus taking several feet from the elevation which must be overcome in carrying terrace water to base grade.

If masonry or concrete check dams are constructed, the size of the outlet ditch will depend on the size of weir notches necessary to carry discharge from terraces. The size of these notches should be

determined from data furnished in the report "Brief Instructions on Methods of Gully Control" by C.E. Ramser. The amount of run-off computed from curves given in these Instructions may be reduced for terraced land in Nebraska, as follows:

Area in acres	Run-off may be reduced to
1	60 percent
10	70 "
30	75 "
100	90 "
Over 100	No reduction

In the construction of check dams in terrace outlets, the curves based on a rainfall frequency of once in 10 years, as shown in the above-mentioned report, may be used as a basis for design of notches. In no case should notches be less than 18 inches deep. This depth may be increased to 24 inches when the width of the structure, using the 18-inch depth, becomes excessive. However, the depth of 24 inches should not be exceeded.

By excavating the outlet to conform to the size of weir notches designed in this manner, the outlet will be broad and shallow and, due to the permanent check dams, will remain so. The outlet should be "step cut" to prevent excessive erosion; by step-cutting is meant excavating the ditch to proper grade and width between permanent dams. Each step will be cut on the terrace line when the permanent structure is located to prevent erosion at the overfall. After the farmer has cut the ditch in this manner little hand excavation is required. There is no chance for the outlet to develop into a deep gully. It can be crossed with all farm machinery and may even be cropped. However, it is not advisable to allow the outlet to become filled with any rank growth as it may become choked, causing the terraces to break or structures to be washed out.

One of the most important parts of any terracing system is the proper design of the terrace outlet and adequate means of protecting this outlet. Terrace outlets should be protected ^{by} vegetation, permanent structures, or a combination of the two. That is, the upper part of the outlet may be protected by vegetation and the lower part by masonry or concrete structures. Where permanent structures are used they should be built as shown in figure 5.

If durable stone, suitable for building purposes, is available this material may be used in a part of the dam as shown. In all cases the base should be of good quality concrete. Dams up to 6 feet in width may be reinforced with hog wire. Above this size 1/2 inch round reinforcing steel should be used, spaced 1 foot centers for the long dimension and 18 inches centers for the short dimension. This applies to the base and also to the body of the dam if this is built,

of concrete. Counterforts or buttresses should be used where dams are greater than 10 feet in length. Maximum spacing of buttresses will depend on the height of the dam and the material used.

The following outline will be followed in construction:

1. The outlet should first be excavated by the use of teams or grader and step cut where permanent structures are to be used. This will reduce the excavation for structures materially.
2. Check dams should be staked out and a "blue top" set as the top of the headwall extension.
3. The foreman should be provided with a sheet showing all vertical dimensions to the "blue top."
4. Excavation should be made for the main body of the dam and stilling basin only. Headwall extensions should not be excavated at this time.
5. Pour base slab, providing keys for main body of dam and wingwalls.
6. Excavate for headwall extensions. These need not be more than 4 inches to 6 inches thick as their only function is that of a core or cut-off wall.
7. If masonry is to be used, start laying up main body of dam and wingwalls together. This gives a much stronger structure than if built separately.
8. Bring headwall extensions up with concrete as masonry is raised.
9. Pour lip wall.
10. If concrete is used for the entire structure it should be formed together and that part of the base poured monolithically. Reinforcing as designated for the base slab may be used for structures up to 4 feet in height. Above that height, a study of stresses should be made and the dam designed accordingly.
11. Use good quality, well mixed mortar not leaner than 1:3:5. The same will apply to concrete. However, the mix will depend on the aggregate available.
12. A grade of $1/4$ to $1/2$ of 1 percent depending on the type of soil may be allowed between the crest of a check dam to the top of the lip of the next dam above.
13. In building dams, particularly where masonry is used, drop the elevation of the weir crest 3 inches below that indicated in design. With enrollee labor it probably will not be possible to

build an exact elevation. It is believed safer to have the weir slightly low than to get it too high and endanger the structure or terrace. If scouring occurs in the terrace channel, the weir can be raised later. On lower dams of a large system the weir may be left as much as 6 inches low as a factor of safety.

A study of the curves in the "Memorandum to ECW Technicians on the Design and Control of Broad, Shallow Terrace Outlet Ditches" shows that for any given drainage area the width of outlet channel must be increased with increases in grades. This increase in the width of the ditch is to reduce hydraulic efficiency of the channel and retard velocities, or prevent velocity increases with increase in grade. The maximum area that can be controlled with vegetation is a function of the grade as the steeper the grade the greater the width of ditch required. This inverse relationship makes it impractical to control large areas on steep grades because of the width of channels it would be necessary to construct. Data in this Memorandum will also be found valuable in designing vegetated spillways for farm ponds and soil-saving dams.

THE USE OF LARGE STRUCTURES IN TERRACE PROJECTS

Projects will at times be encountered where the use of large structures is required to drop water to a base grade. The principal factor in the consideration of such structures is that the cost per acre protected be kept within economic limits. This will depend on the number of acres protected and the value of the land. Wherever possible, large structures should be avoided. Many times, by careful study, it will be possible to cut water out of the heads of large gullies by means of a diversion ditch or a system of terraces, and drop it down to base grade by a series of low check dams, each of which serves a lower terrace.

In other instances earth fills may be constructed across large gullies and the overflow water handled as above. It is preferable that large structures be built only in connection with terracing projects. However, occasions may arise where such structures seem justified, that is, where a large gully is eroding back into valuable, fairly level farm land. Unless terracing is done as the landowner's cooperative share of the project, he should furnish a part of the materials so as to be a partner in the project. In all cases, power for building fills should be furnished by the landowner.

Where large structures are necessary, either a drop inlet culvert or an overfall dam may be built, depending on local conditions.

A careful study should be made both from an engineering and an economic standpoint before work is undertaken. Brief Instructions on Methods of Gully Control by C.E. Ramser may be used as a basis of design.

There will probably be many opportunities to utilize a concrete road culvert already in place as an erosion control structure by constructing a concrete riser on the upstream end. If any appreciable acreage is protected, the construction of these risers will be good practice whether or not terraced land is affected. Written consent of the proper authorities must be received before such construction is started and, in the case of terraced land, a study should be made to determine whether the culvert capacity is sufficient to take any additional water that may be brought to the culvert by terraces.

TERRACING IN CONNECTION WITH ORCHARD LANDS

The problem of conservation of soil on orchard lands is an important one, especially in southeastern Nebraska. Such lands can be materially benefitted by terracing. For best results, the terracing should be done before the orchard is planted.

Very little experimental data is available on the use of terraces in this particular field, but it is believed that a practice as outlined below will be beneficial.

For ease of cultivation, and harvesting, the rows should be parallel. It is believed that the best results will be obtained by planting trees on the terraces. Therefore the terraces should be parallel unless the land slopes are very irregular. Since the normal planting distance is two rods, this is a good distance to use between terraces on the steeper slopes. On more gentle slopes this distance may be doubled and a row of trees planted between the terraces.

Since the principal function of orchard terracing is moisture conservation, these terraces should be level. Two factors are involved in a layout of this kind. The terraces should be level and parallel. This probably will necessitate some cut and fill, but by first making a fairly accurate sketch map and giving the problem careful study, this can be reduced to a minimum.

Orchard terraces should be partially closed at the ends. If terraces are 18 inches high it is suggested that a sodded levee 6 inches high be thrown up at each end of the terrace. This will conserve the water from all small rains but will provide an outlet, without overtopping the terraces, during heavy rains. Some project of this type should be developed if possible.

SUMMARY

Terracing should be the foundation of the soil erosion control and moisture conservation program. Terracing should primarily be done on valuable agricultural land as a conservation measure rather than on worn-out and badly gullied land as a reclamation project.

Permanent pasture and tree planting should be advocated for badly eroded land unfit for agriculture. Permanent pasture should be recommended for steep slopes even though terraced.

A sketch map and thorough study should be made before terracing is started.

The watershed or terracable area should be considered rather than property lines.

Particular attention should be given to terrace outlets.

Vegetation should be used as protection for terrace outlets whenever possible.

Permanent structures should be built only where necessary but should be well built.

Backfill around permanent structures should be puddled.

Terracing should begin at the top of the slope and should be adequate to take care of the runoff.

Terrace outlets should be protected against erosion down to base grade or a nonerosive substance. Vegetation should not be depended on as protection below a system of permanent structures unless the draw is broad, with little grade, and well sodded.

The reports herein suggested should be used as a basis of design.

Large structures should be built only when absolutely necessary and preferably in connection with large terracing systems.

Terracing may well become an important part of orchard practice.

The agronomic program to be followed by the farmer should be a part of the contract.

Trees should be planted wherever they will assist in the control of erosion by wind or water.

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